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Feeding of cod juveniles on the Newfoundland Shelf

by A.Yu. Bulatova and T.N. Turuk

Fairly complete data are available on the distribution, migrations and feeding of market-sized cod on the Labrador-Newfoundland Shelf, whereas the data on cod juveniles from one to three years of age are very limited. I.Ya. Ponomarenko (1958, 1961, 1968) provides some data on the feeding of 3rd—4th-year Barents Sea cod.

During the trawl surveys of 1968-1978, aimed mainly at determining the abundance of cod in successive generations, we attempted, on the basis of the material collected, to establish the characteristics and trophic dependence of distribution of cod juveniles on the Newfoundland Shelf.

Material and method. Observations were conducted in April—August, and in some cases March—September. The survey was carried out with the standard spacing of trawling stations, and included the following microregions (based on the zoning accepted in the USSR in 1971) or zones (ICNAF zoning): Notre Dame Bay (North Newfoundland bank, 3*K*); St. John's (NE slope of Grand Bank of Newfoundland, 3*L*), Flemish Cap (Flemish Cap, 3*M*); South Newfoundland (SE slope of Grand Bank, 3*N*; SW Newfoundland (SW slope of Grand Bank, 3*O*); Burin, St. Pierre (St. Pierre bank, 3*P*).

At the designated points, hour-long trawling was carried out with a bottom trawl (diagram 1625 A) with an inserted bag made of fine mesh (10 mm) capron netting. At the same time, the water temperature was measured at 0, 10, 20, 30, 50, 100, 150, 200, 300, 400 and 500 metres and in the near-bottom layer.

Fish up to 40 cm in length were regarded as juveniles. All of the fish caught were measured. The data on the number of juveniles in the catches were plotted on a chart, and catches similar in size were connected by isolines.

In the case of large catches, we analyzed the age and sex composition of the fish, determined the degree of stomach fullness and the qualitative composition of the food (frequency of occurrence of food organisms), and weighed the fish and the liver. A sample of stomachs (30) was fixed in 4% solution of Formalin for quantitative analysis of the cod diet in each zone.

Further processing of the material was carried out by the quantitative-gravimetric method. The contents of each stomach were examined and determined under a МБС-1 binocular lens, each organism swallowed by the cod was identified taxonomically (to the species wherever possible), and the following values were calculated: the frequency of occurrence of each food item, calculated as a percentage of the stomach contents; the degree of stomach fullness; the overall index of fullness; the individual index of fullness; relative fatness (%); Fulton's condition factor; the condition factor (%) expressed as the ratio of Fulton's condition factor to Noskov's condition factor (long-term mean weight of fish of the same length) (A.S. Noskov, 1956).

The mean index, fatness and condition factor for the sample as a whole were calculated as the arithmetical mean of these indices in individual fish.

This paper contains the results of field tests of the diet of cod juveniles, as well as 34 lab-processed samples (1020 specimens) collected during 1968-1978.

Distribution of cod juveniles. We have long known that schools of fish appear in the same areas of the banks, which K.G. Konstantinov (1967) figuratively refers to as "natural traps". These "traps" include areas with an undulating hilly relief, shelves on the slopes of the banks, as well as troughs and depressions where the velocity and direction of currents change and local gyrals form (Rvachev, 1972; Matishov, Rvachev, 1977). During their study of the geomorphological structure of shelves, B.N. Kotenev et G.G. Matishov (1972) and Kotenev (1976) came to the conclusion that, in the case of a broad and weakly dissected shelf (like the Labrador-Newfoundland Shelf), commercial stocks of fish consistently form along its outer margin and along the edges of deep troughs from which organically enriched abyssal waters of the continental slope flow onto the shelf.

In their opinion, the most favourable conditions for the concentration of fish and other hydrobionts form on steep slopes dissected by canyons.

The relationship between concentrations and the areas of vertical and horizontal gyrals was traced in numerous biological subjects (Meisner, Tot, Shilov, 1974; Fetter, 1977; Bozhkov, 1973; Yelizarov, Movchan, 1973; Yelizarov, 1972; Barinov, 1977). It has been noted that the density of concentrations increases at the boundaries of currents differing in their physicochemical characteristics, and the depth of the concentrations depends on the depth of the thermocline. Similar results have been obtained by ichthyologists studying the distribution of cod, who have found that fish congregate in frontal waters and disperse as the thermocline decreases (Maslov, 1968; Karasev, Sauskan, 1963; Templeman, May, 1965; Templeman, 1966; Brunel, 1971; Jean, 1964).

As we know, the behaviour, distribution and density of fish stocks are greatly influenced by feeding conditions. During the spring-summer period, the cod inhabiting the deep waters of the Labrador-Newfoundland Shelf migrates to the shallow parts of the banks to feed, some of the fish following capelin migrating coastward to spawn (Postolaky, 1978; Templeman, 1965). The density of cod stocks increases during the period of feeding on group fishes such as the capelin, sand lance, herring and perch. Following the capelin, the cod approaches the coast in the upper heated-through layer of water; when feeding on the perch, it stays deeper than when it feeds on its own young (Templeman, 1965).

Our investigations have shown that the distribution of cod juveniles shows the same tendencies as that of commercial-size individuals. We have found that, despite the extensive range of distribution of juvenile cod (from the smallest depths up to 500 m, waters with a bottom temperature from -1.6 to 8°C), they keep mainly to depths of less than 350 m, in waters with temperatures from -1 to 3°C. The data on catches in different microregions point to the nonuniformity of their distribution, i.e. areas with a minimum number of juveniles and locations with large concentrations on the shelf almost coincide from year to year (Fig. 1). For example, only a few cod juveniles (25 per hr of trawling) are usually found in the catches on the Grand Bank from depths under 100 m where the temperature is below zero. The juveniles usually congregate along

the eastern slopes of the bank, and in shallow waters with temperatures over 0°C.

The location of aggregations is characterized by a high degree of constancy. We known of several areas where aggregations of juveniles are observed during different years and seasons. In the St. John's microregion (zone 3*L*), one such area is located at a latitude of 48-49°, and a second area at approximately 47° (see Figs. 1, 2). The constancy of these aggregations is confirmed by the catches at the stations with coordinates of 47°11' N and 47°22' W, where, during different years (from 1970 to 1977) and seasons (from April to September), the number of juveniles caught in one hour of trawling at depths of 240-340 m in waters with a bottom temperature of 1.1-3.8°C varied from 100 to 777.

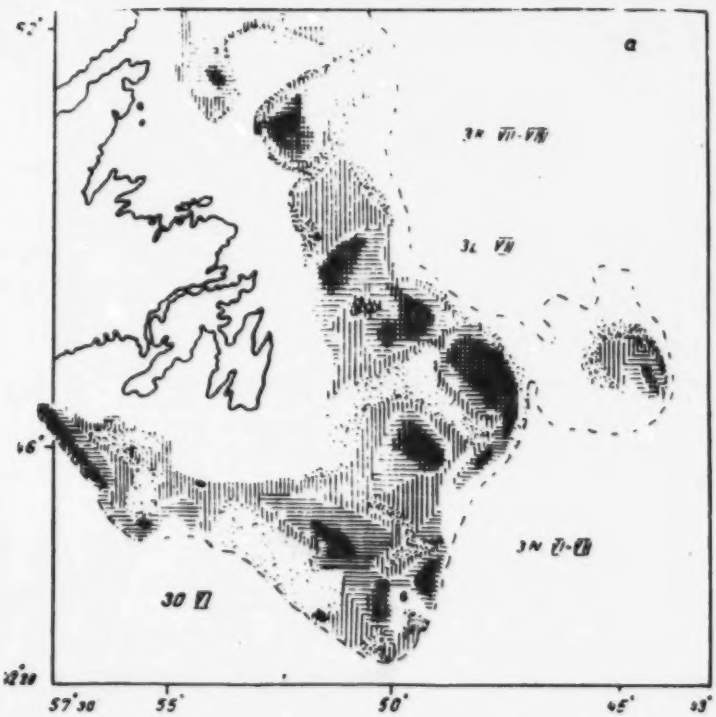
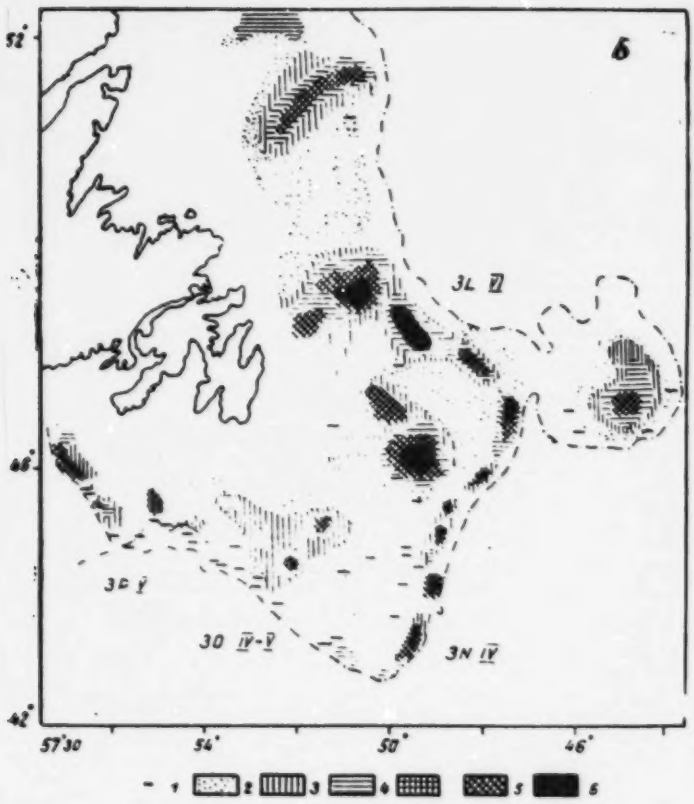


Fig. 1. Distribution of cod juveniles (no. of fish caught) on Newfoundland Shelf in May-August 1971 (a) and April-July 1972 (b): 1 - empty trawls, 2 - 25, 3 - 50, 4 - 100, 5 - 300, 6 - over 300

(Fig. 1 continued)



A large part of the St. John's microregion is occupied by waters of below-zero temperature, which, depending on the temperature conditions of the year, are found at the 20-200 m level (Buzdalin, Yelizarov, 1962; Burmakin, 1976; Burmakin et al., 1977; Templeman, 1972). The juveniles keep mainly to depths of 180-300, most commonly to waters with a bottom temperature of 0-3°C; during certain years, when feeding on capelin, juveniles can be found at depths of 150-200 m, in waters of below-zero temperature. The stability of juvenile cod aggregations in the northern part of the microregion is apparently due to the gyral that forms when the Labrador Current branches (Buzdalin, Yelizarov, 1962; Kudlo, Burmakin 1972), and to the presence of foraging capelin. The concentrations of juveniles at 47° increase due to an increase in the steepness of the slope (Rvachev, 1972), and to the abundance of sand lance in this area and farther south along the slope.

In the shallow (less than 100 m) part of the St. John's microregion, aggregations of juveniles have been noted east and southeast of the Virgin Rocks for a number of years (see Figs. 1, 2). Here, the juveniles usually keep to waters with a bottom temperature greater than 0°C, which flow northward from the southern part of the shallow waters of the Grand Bank of Newfoundland.

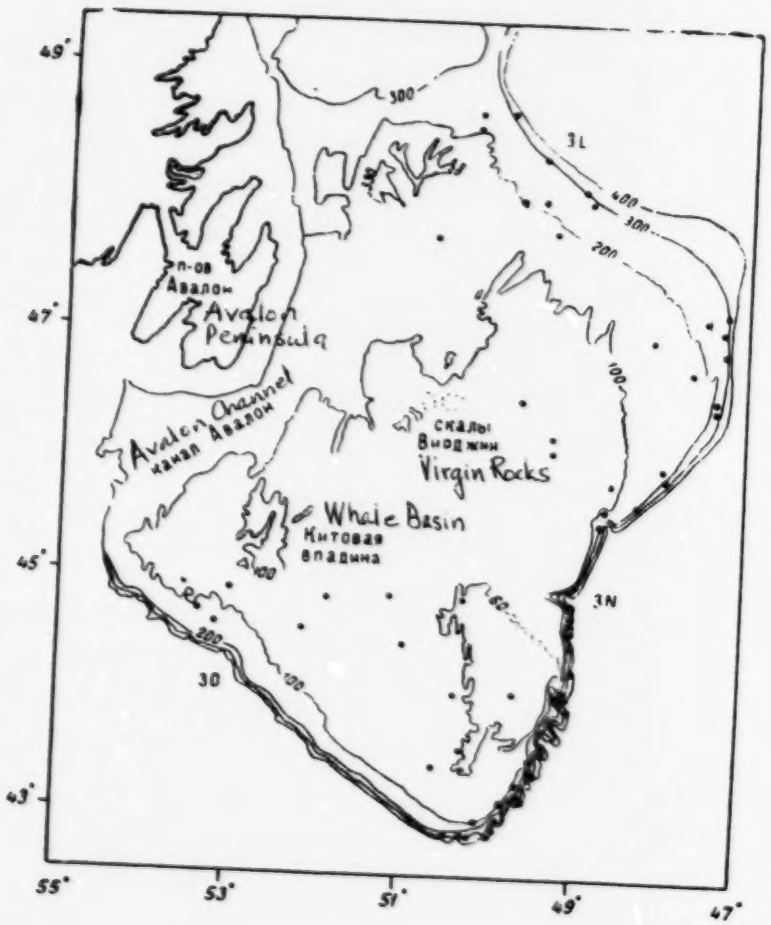


Fig. 2. Bottom topography of the Grand Banks (Bathymetric chart..., 1970) and juvenile cod catches of more than 300 fish per hr of trawling (marked by dots) during 1970-1977)

Cod juveniles are particularly abundant in the upper parts of the canyons of the steep southeastern slope of the bank (S Newfoundland microregion) at 45° N lat, and also from 44° N lat southward along the slope to the southern end of the bank (Fig. 3). The catches of juveniles on this slope often amount to 300-500 specimens, and sometimes 1000-2000 specimens, per hour of trawling. The fish congregate mainly at the boundary and below the layer with below-zero temperatures (table 1); here, as in the St. John's microregion, the cod keeps to waters of below-zero temperature when it feeds on capelin.

Table 1. Average catches of cod juveniles* in the S Newfoundland microregion in relation to depth and the temperature of the near-bottom waters in April-May 1972, 1976 and 1977

Depth, m	Temperature, °C								
	-1.5--1.1	-1.0--0.01	0.01-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	6.1-7.0	8.1-9.0
Up to 100	2/1	13/5	21/24	18/20	10/47	-	-	-	-
101-200	4/17	22/370	13/528	-	-	-	2/517	-	-
201-300	-	3/271	10/365	17/444	3/345	-	-	1/0	2/18
301-400	-	-	-	2/695	3/404	2/55	-	1/2	-
401-500	-	-	-	-	2/0	-	-	-	-

*Here and in table 2: numerator - number of trawlings, denominator - average number of cod juveniles in catch per trawling

In the S Newfoundland shallows (depth less than 100 m), the take of juveniles in April is insignificant, up to 30 per hour of trawling. At the end of May—June, when the temperature of the near-bottom waters increases to 2-3°C and the capelin migrates to the spawning grounds (Buzdalin, Yelizarov, 1962; Templeman, 1972; Kovalyov, Kudrin, 1973), the density of the juvenile cod aggregations increases considerably (see Fig. 1). In 1973 and 1978, the number of juveniles in the catches in the southeastern shallows amounted to 1600-1888 specimens per hour of trawling. It is significant that, beyond the capelin spawning grounds

where the young of the cod congregate, the take of cod juveniles in the rest of the shallow areas remains low.

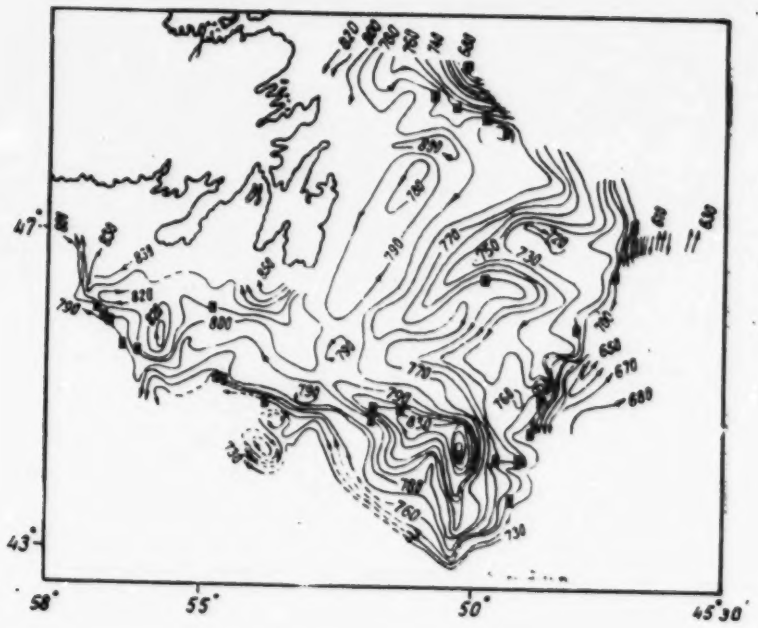


Fig. 3. Map of geotrophic currents in the 0-200 m layer, according to a survey in May-July 1970 (Kudlo, Burmakin, 1972). Squares mark catches of cod juveniles (over 250 per hour of trawling) in May-July 1970

According to B.P. Kudlo and V.V. Burmakin (1972), a steady anticyclonic gyral is observed over the southeastern shallows of the Grand Banks (see Fig. 3). The location of large concentrations of juveniles coincides with the centre of the gyral, as well as with the regions of maximum convergence of the isodynamic lines. Apparently, the young cod find these areas the best for foraging, as aggregations of juveniles remain in the southeastern shallows up to September. For example, the two largest catches here in September 1975 amounted to 272 and 619 specimens.

The juveniles begin their migration to the shallows from the slopes of the southern end of the Grand Banks, from where they are forced out from the warm waters of the Gulf Stream (Burmakin et al., 1977). In certain areas of the slope, the juveniles forced against the bottom by the

cold waters of the Main Labrador Current remain in the deep layers throughout the year (Table 2).

Table 2. Average catches of cod juveniles at different depths in April-September 1968-1978 in the S Newfoundland microregion

Depth, m	April	Apr-May	May			June				July	Sept
	1972	1976	1968	1969	1977	1970	1971	1974	1978	1973	1975
50-100	21/4	26/20	18/33	22/23	17/46	23/147	23/54	28/20	16/134	36/93	39/12
101-150	7/69	6/392	5/26	8/222	5/327	7/228	5/24	3/36	5/82	6/8	6/5
151-200	7/80	10/532	3/378	7/231	5/716	13/126	9/249	11/171	6/74	7/117	8/18
201-250	8/206	8/149	4/75	5/83	7/872	8/126	6/359	7/413	5/193	4/114	6/18
251-300	6/166	8/227	-	4/172	5/363	2/338	5/360	6/113	3/19	1/0	6/184
301-350	2/699	-	-	-	1/171	1/32	-	2/88	5/1	1/17	3/147
351-400	1/880	2/61	-	1/0	3/57	-	-	-	1/3	-	-
401-450	-	1/29	-	-	2/1	-	-	-	1/0	-	-
451-500	-	-	-	-	1/0	-	-	-	1/0	-	-

On the Gulf-Stream-warmed southwestern slope of the bank (SW Newfoundland microregion) where the temperature of the near-bottom waters at depths of 100-200 m can go up to 7-11°C (Burmakin, 1977), the cod juveniles congregate in the areas washed by the Labrador Current (on the slopes of the southern end of the bank, at the Avalon channel, and southeast of the cold-water Whale Basin (see Figs. 2, 4). During the spring—summer period, the juveniles usually keep to depths of 80-150 m; the largest catches from this part of the shelf do not exceed 200-300 fish (with the exception of 506 fish in 1973).

From April—May to June—July, a part of the stock of juveniles shifts in the direction of the spawning migration of the capelin from the southwestern part of the shallow areas to the southeastern and northeastern part of the bank.

On the Flemish Cap bank, the survey seasons varied from March to July during the different years. Cod juveniles are encountered on all the

slopes of the bank (predominantly at depths up to 300 m), but the highest concentrations are noted on the steep eastern and southern slopes dissected by canyons and flanged with ledges (Rvachev, 1972; Litvin, Rvachev, 1962). In March 1976, the largest number of juveniles (10,040) was caught on the eastern slope of the bank at a depth of 250 m. Since the temperature of the near-bottom waters on the bank is relatively constant (3-4°C) during the different seasons (Buzdalin, Yelizarov, 1962; Burmakin, 1976; Templeman, 1972), its effect on the formation of aggregations is obviously less significant than the effect of the dynamics of the water masses, bottom topography (Boytsov, Kudlo, 1977; Kudlo, Burmakin, 1972; Kudlo, Borovkov, 1975) and feeding conditions.

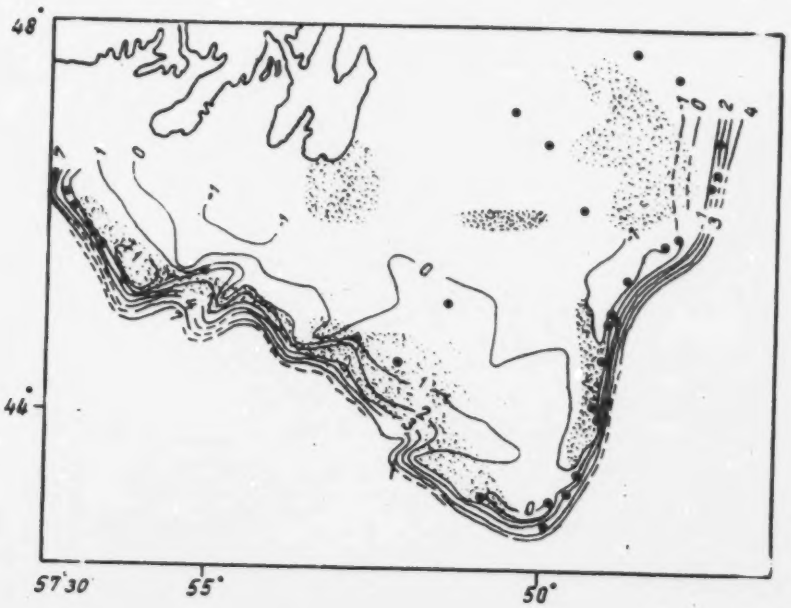


Fig. 4. Temperature of near-bottom waters in April—May 1972, landings of cod juveniles totalling more than 100 specimens per hour of trawling (large dots), and aggregations of capelin (small dots) on the Grand Bank

During the years of high abundance of cod juveniles, we also noted large aggregations (over 100 specimens per hour of trawling) on the northern and western slopes of the bank, and the range of their distribution expanded simultaneously with an increase in depth, i.e. during the abundant year of1976, the young of the cod spread to depths exceeding 450 m, whereas practically no juveniles were encountered beyond the 350-metre depth during the years of low abundance (1972, 1978).

In Notre Dame Bay (zone 3*K*), the catches from the deep waters of the abyssal trough contained either no juveniles at all, or individual specimens only; in the shallow seaward part of the shelf, they are distributed comparatively uniformly at depths up to 300 m. Somewhat higher concentrations are usually noted either in the southwestern part of the seaward area adjacent to the trough, or on its northeastern outer edge. Coastal aggregations (catches of 100 specimens per hour of trawling) were observed in 1970, 1971, 1976 and 1978; during the rest of the years of this period, the number of cod juveniles in this area was insignificant.

Feeding of cod juveniles in different areas and at different depths. Despite the great diversity of food organisms encountered in the stomachs of cod juveniles on the Grand Bank, only a few play an important part in their diet (Table 3, Fig. 5). In the majority of the areas studied, capelin, sand lance, hyperiids (predominantly *Themisto*), gammarids, decapods (predominantly crabs), euphausiids, and, in some areas, plankton and worms constitute the basic food of cod juveniles.

The diet of cod juveniles consists primarily of fish, particularly sand lance (26%)* , capelin (15.7%) and decapods (16.5%); second place in mass is occupied by euphausiids (9.6%), hyperiids (8.1%) and gammarids (5%), and third place by worms (3.2%) and plankton (4.9%).

First place in the frequency of occurrence is occupied by the sand lance (41.4%) and various species of amphipods, gammarids (38.9%) and hyperiids (30.6%), second place by plankton (25.4%) and capelin (23.5%), and third place by euphausiids (22%) and worms (21.2%).

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* per cent ratio of individual index of fullness to overall index of fullness given here and hereinafter.

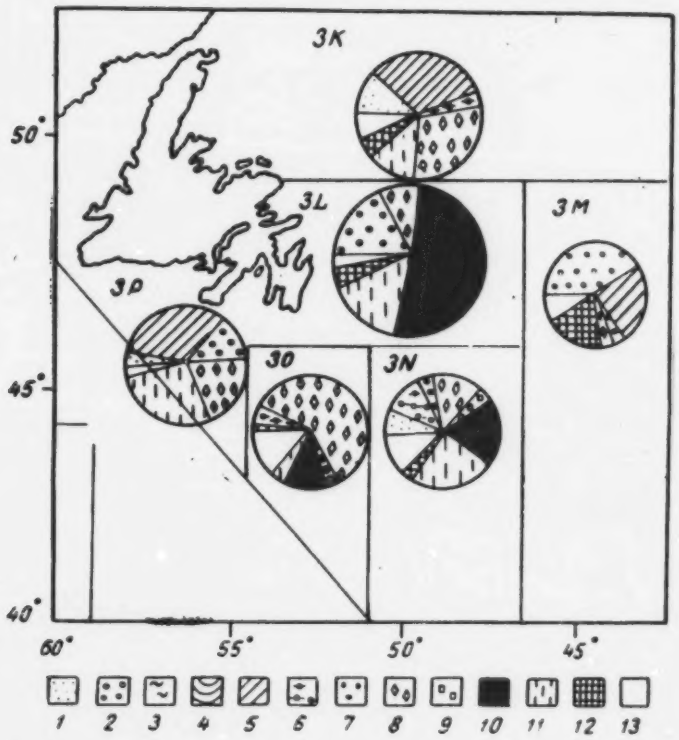

Fig. 5. Quantitative feeding indices of cod juveniles on the Newfoundland shelf. Radius of circle proportional to the overall index of fullness.
1 - polychaetes, 2 - plankton, 3 - mysids, 4 - isopods, 5 - *Themisto*, 6 - benthic amphipods, 7 - euphausiids, 8 - decapods, 9 - mollusks, 10 - sand lance, 11 - capelin, 12 - digested fish, 13 - miscellaneous

As we know, the main food of cod juveniles in the southern part of the Barents Sea consists of immature fish (cod, arctic cod, herring, capelin), as well as euphausiids and hyperiids; on the whole, fish in the diet of cod juveniles sometimes comprises 72-76% by mass, and the frequency of its occurrence in cod stomachs increases with age. During the summer months, euphausiids become the main food item of cod juveniles in the southern part of the Barents Sea. During certain years, benthic organisms (worms, amphipods, bottom-dwelling crustaceans) constitute 30-33% of all the food consumed by the young of the cod (Ponomarenko, 1958, 1961, 1968).

Table 3. Composition of food consumed by cod juveniles on the Newfoundland shelf (1972-1976)

Food item	3K		3L		3N		3O		3P		3M	
	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%
Hydroids	0.3	3.3	-	-	27.4	12.2	-	-	-	-	-	-
Sponge	-	-	-	-	226.3	8.5	-	-	-	-	-	-
Phascolosoma	33.2	3.3	-	-	-	-	-	-	6.9	3.5	-	-
Onuphis conchylega	135.6	33.0	-	-	-	-	-	-	1.7	7.1	-	-
Maldanidae	38.7	8.3	46.3	3.3	-	-	-	-	-	-	-	-
Anaitides groenlandica	34.0	13.3	-	-	6.9	8.3	-	-	35.2	7.0	27.6	6.9
Aphroditidae	31.0	3.3	-	-	252.0	6.6	-	-	19.5	3.4	11.4	3.8
Maldane sarsi	-	-	-	-	22.0	3.3	-	-	-	-	-	-
Ampharetidae	0.5	3.3	-	-	-	-	-	-	-	-	-	-
Spiochaetopteris	-	-	-	-	0.2	3.3	-	-	-	-	-	-
Sedentaria	-	-	-	-	485.3	28.0	-	-	-	-	-	-
Travisia	-	-	-	-	17.6	3.3	-	-	-	-	-	-
Terebellidae	62.4	3.3	-	-	-	-	48.9	3.3	-	-	-	-
Nereis sp.	14.3	3.3	19.6	6.7	-	-	6.6	5.0	-	-	-	-
Stylarioides plumosus	-	-	-	-	-	-	-	-	29.5	7.1	-	-
Polychaetes	36.2	27.8	19.0	4.4	38.1	7.6	28.7	11.1	1.8	3.5	9.2	5.1
Worms	-	-	3.1	3.3	33.5	4.3	5.0	3.3	-	-	20.9	6.8
Nicomache	-	-	-	-	-	-	-	-	45.2	10.7	-	-
Metridia longa	0.5	6.6	-	-	56.5	35.5	-	-	-	-	71.1	19.0
Metridia lucens	-	-	-	-	-	-	-	-	-	-	-	10.0
Sagitta sp.	-	-	-	-	40.5	7.6	-	-	42.1	13.7	8.1	3.3
Pareuchaeta norvegica	-	-	-	-	-	-	-	-	-	-	61.6	63.2
Pareuchaeta sp.	-	-	-	-	-	-	-	-	-	-	0.8	3.8
Calanus finmarchicus	-	-	1.2	3.3	16.8	16.6	-	-	-	-	-	-
Calanus hyperboreus	-	-	-	-	-	-	-	-	-	-	0.2	3.3
Calanus sp.	-	-	0.3	3.3	0.6	3.3	-	-	-	-	0.1	3.3
Calanoidea	-	-	-	-	-	-	-	-	-	-	0.2	3.3
Limacina retroversa	-	-	-	-	-	-	-	-	-	-	10.5	30.0

(Table 3 continued)

Food item	3K		3L		3N		3O		3P		3M	
	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%
Chaetognatha	-	-	-	-	-	-	-	-	-	-	72.4	20.0
Ctenophores	-	-	-	-	-	-	-	-	-	-	20.8	6.7
Aetideidae	-	-	-	-	-	-	-	-	-	-	7.0	3.4
Oikopleura	-	-	-	-	-	-	-	-	-	-	2095.9	43.9
Mesidothea entomon	-	-	-	-	16.9	4.9	-	-	-	-	-	-
Mesidothea sp.	4.4	15.0	15.5	9.9	3.8	5.3	5.5	13.3	-	-	0.8	10.0
Diastylis rathkei	-	-	-	-	5.3	5.9	-	-	-	-	-	-
Diastylis sp.	-	-	-	-	2.3	3.4	-	-	-	-	-	-
Cumacea	-	-	-	-	0.5	3.3	-	-	-	-	-	-
Isopoda	1.0	3.3	-	-	-	-	-	-	-	-	0.2	3.3
Calathura brachiata	5.0	6.7	-	-	-	-	-	-	-	-	-	-
Synidothea nodulosa	-	-	-	-	11.1	8.3	-	-	-	-	-	-
S. marmorata	-	-	-	-	9.1	5.5	-	-	-	-	-	-
Idothea sp.	-	-	7.3	3.3	21.5	6.4	1.2	3.3	-	-	-	-
Themisto compressa f. *bispinosa*	812.5	36.7	-	-	-	-	41.6	6.6	1045.5	31.4	678.3	24.8
Th. compressa f. *compressa*	65.0	8.3	19.7	3.3	16.1	6.4	1.1	3.3	65.2	20.6	741.9	35.9
Th. abyssorum	-	-	-	-	1.1	6.6	-	-	-	-	-	-
Th. libellula	-	-	1.9	3.3	-	-	-	-	-	-	-	-
Themisto sp.	75.0	21.1	63.2	15.0	13.9	6.9	9.0	8.3	399.4	19.0	85.5	17.3
Young of *Themisto*	-	-	-	-	0.7	3.3	-	-	-	-	1.5	3.8
Hyperia sp.	2.6	3.3	-	-	-	-	-	-	-	-	-	-
Ampelisca eschrichti	14.4	4.9	-	-	43.2	4.1	14.3	3.3	-	-	109.5	3.8
Ampelisca sp.	-	-	-	-	99.1	20.0	2.6	3.3	-	-	-	-
Ampeliscidae	-	-	-	-	36.3	6.7	29.7	13.3	-	-	-	-
Anonyx nugax	5.9	3.3	12.3	6.7	-	-	16.1	9.9	1.8	3.4	0.6	3.3
Ericthonius difformis	0.5	3.3	-	-	3.6	8.2	-	-	-	-	-	-
Syrrhoë crenulata	1.9	3.3	-	-	-	-	-	-	-	-	-	-

(Table 3 continued)

Food item	3K		3L		3N		3O		3P		3M	
	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%
Dulichia sp.	5.0	6.7	-	-	-	-	-	-	-	-	-	-
Caprella sp.	-	-	-	-	84.9	6.5	-	-	-	-	-	-
Caprellidae	3.7	3.3	-	-	285.3	22.5	27.2	6.6	-	-	-	-
Parapleustes	-	-	-	-	38.6	3.3	-	-	-	-	-	-
Haploops robusta	-	-	-	-	5.4	3.3	-	-	-	-	-	-
Haploops sp.	-	-	-	-	63.8	5.0	-	-	-	-	-	-
Monoculodes sp.	-	-	-	-	118.1	13.7	-	-	-	-	-	-
Tmetonyx sp.	-	-	-	-	2.5	8.0	-	-	-	-	-	-
Crictonius sp.	-	-	-	-	27.4	4.0	-	-	-	-	-	-
Rhachotropis aculeata	8.0	6.7	-	-	-	-	-	-	-	-	-	-
Rhachotropis sp.	21.8	4.9	-	-	15.7	3.2	25.0	6.6	-	-	-	-
Unciola leucopis	-	-	-	-	2.6	5.0	-	-	-	-	-	-
Unciola irrorata	-	-	0.3	3.3	9.1	5.5	117.2	8.3	-	-	-	-
Unciola sp.	-	-	-	-	1.9	6.0	54.5	20.0	-	-	-	-
Gammaridae	-	-	-	-	102.6	10.0	-	-	-	-	-	-
Amphipoda	34.8	31.1	136.6	41.0	288.5	40.0	81.6	22.5	29.3	23.0	106.2	15.0
Young of Amphipoda	-	-	-	-	-	-	-	4.4	3.8			
Thysanoessa longicaudata	-	-	238.0	3.3	-	-	-	-	-	-	-	-
Th. raschii	-	-	1908.6	25.0	356.1	25.3	4.2	3.3	275.9	24.0	-	-
Th. inermis	-	-	199.8	6.7	1.8	3.2	-	-	7.6	3.4	-	-
Meganyctiphanes norvegica	-	-	5.8	3.3	-	-	-	-	410.6	27.3	-	-
Euphausiacea	3.8	6.7	1121.1	28.7	155.0	16.9	50.6	15.0	110.3	13.7	7.4	7.6
Young of Euphausiacea	-	-	-	-	0.6	3.3	1.9	3.3	3.8	3.4	7.4	3.8
Pandalus borealis	497.6	23.3	205.3	10.0	115.6	4.6	59.6	3.3	49.6	3.4	-	-
Pandalus sp.	66.9	9.9	96.5	6.6	-	-	-	-	-	-	-	-
Hetairus polaris	25.7	3.3	-	-	19.5	3.3	8.9	3.3	-	-	27.6	3.8
Spirontocaris spinus	-	-	2.4	3.3	-	-	-	-	-	-	-	-
S. securifrons	-	-	-	-	12.0	3.3	18.5	3.3	-	-	-	-
Spirontocaris sp.	-	-	-	-	2.8	3.3	-	-	-	-	-	-

(Table 3 continued)

Food item	3K		3L		3N		3O		3P		3M	
	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%	Ind. of fulln,%	Fr. of occur,%
Shrimp	125.0	12.2	195.7	14.9	49.4	4.5	26.8	11.6	9.6	3.5	19.1	10.9
Young of shrimp	3.0	3.3	9.6	10.0	9.0	6.6	-	-	-	-	3.6	3.8
Hyas araneus	-	-	-	-	26.4	3.3	2379.2	40.0	186.9	3.4	-	-
H. coarctatus	-	-	11.2	3.3	29.1	3.3	-	-	-	-	-	-
Hyas sp.	2.3	3.3	-	-	43.8	10.0	161.8	13.3	873.0	17.2	-	-
Pagurus pubescens	-	-	-	-	458.0	24.0	61.3	5.5	-	-	55.2	10.2
Pagurus sp.	-	-	-	-	8.6	3.3	-	-	-	-	-	-
Larvae of Paguridae	-	-	-	-	1.1	6.6	-	-	-	-	-	-
Polynices	0.8	3.3	-	-	-	-	-	-	-	-	-	-
Crab	174.3	6.7	990.9	33.0	373.1	11.1	355.9	13.3	-	-	7.8	6.8
Decapoda sp.	-	-	-	-	17.7	3.3	-	-	3.8	3.5	35.6	5.0
Digested crustaceans	17.7	6.7	43.3	3.3	12.4	5.2	246.5	33.3	-	-	61.0	3.8
Gastropoda	9.1	3.3	72.6	3.3	90.9	3.6	123.2	8.3	30.0	10.7	45.4	3.8
Sipho	-	-	0.3	3.3	-	-	-	-	-	-	-	-
Buccinum	-	-	-	-	227.1	8.5	1.8	3.3	-	-	-	-
Bivalvia	-	-	21.6	3.3	-	-	0.6	3.3	-	-	-	-
Squid	-	-	4.1	3.3	1.9	4.1	-	-	-	-	21.9	6.7
Ophiura sarsi	0.5	3.3	0.2	3.3	-	-	-	-	-	-	147.5	3.8
Ophiura sp.	1.4	3.3	-	-	-	-	-	-	-	-	6.0	6.7
Holothurians	24.4	3.3	-	-	56.5	3.3	-	-	-	-	-	-
Thyonidium sp.	-	-	-	-	-	-	187.1	3.3	-	-	-	-
Actinians	-	-	-	-	11.0	3.3	-	-	-	-	-	-
Ascidians	-	-	-	-	12.9	3.3	-	-	-	-	-	-
Mallotus villosus	352.2	15.0	2766.9	31.3	2965.6	32.9	167.2	10.0	1706.5	28.5	298.4	3.6
Ammodytes dubius	-	-	10567.5	86.5	2295.5	24.4	639.1	13.2	-	-	-	-
Myctophum	-	-	-	-	-	-	-	-	-	-	295.5	3.4
Lumpenus	-	-	-	-	-	-	-	-	-	-	340.8	3.3
Gobies	-	-	-	-	54.6	3.2	-	-	-	-	-	-
Young of halibut	-	-	-	-	23.0	7.5	-	-	-	-	-	-
Young of perch	81.6	8.3	-	-	-	-	-	-	-	-	80.7	3.3
Wolffish larvae	2.1	3.3	-	-	-	-	-	-	-	-	-	-
Larvae of Pleuronectidae	-	-	10.5	3.3	-	-	-	-	10.0	3.3	-	-

(Table 3 continued)

Food item	3K		3L		3N		3O		3P		3M	
	Ind. of fulln,‰	Fr. of occur,%	Ind. of fulln,‰	Fr. of occur,%	Ind. of fulln,‰	Fr. of occur,%	Ind. of fulln,‰	Fr. of occur,%	Ind. of fulln,‰	Fr. of occur,%	Ind. of fulln,‰	Fr. of occur,%
Young of *Lycodes*	-	-	415.8	6.7	-	-	-	-	-	-	-	-
Larvae of *Lycodes*	-	-	226.2	6.7	-	-	-	-	-	-	-	-
Searobin larvae	-	-	-	-	-	-	6.3	3.3	-	-	-	-
Fish larvae	-	-	-	-	6.3	6.7	5.6	3.3	-	-	-	-
Fish eggs	-	-	-	-	359.8	11.6	-	-	-	-	-	-
Amphipod eggs	-	-	-	-	69.1	6.7	-	-	-	-	-	-
Eggs (with minute stones)	-	-	-	-	449.2	14.9	-	-	-	-	-	-
Digested fish	81.0	8.3	51.9	4.4	123.4	8.6	49.7	5.0	48.6	10.5	95.3	28.3
Digested food	39.6	11.6	25.8	3.3	44.1	7.3	36.8	5.5	19.2	3.5	205.2	8.6
Stones, substrate	0.5	3.3	3.4	8.1	8.4	4.6	19.6	15.0	11.9	10.7	2.0	3.5
Overall index	2995.6		19542.4		11567.7		5085.0		5480.4		5915.1	

* * *

Note: Index of fullness given in ‰ - transl.

Thus, the qualitative composition of the food consumed by cod juveniles in the NW Atlantic and Barents Sea differs somewhat. The main difference lies in the species composition of the fish consumed by them. The consumption of euphausiids in the Atlantic has a less distinct seasonal periodicity as compared with the Barents Sea. The diet of cod juveniles in the NW Atlantic also contains more benthic amphipods (gammarids) than in the Barents Sea.

Feeding is also closely related to the distribution of the young, and is characterized by significant local differences.

Themisto (25.5%) and plankton (39.8% *Oikopleura*), as well as anchovy and the young of perch (18.8%), small shrimp and benthic amphipods occasionally (2.5 and 3.7%) were encountered in the stomachs of cod juveniles on the Flemish Cap bank (Fig. 6). Cases of cannibalism become more frequent when the numbers of cod juveniles on Flemish Cap are high (Templeman, 1965).

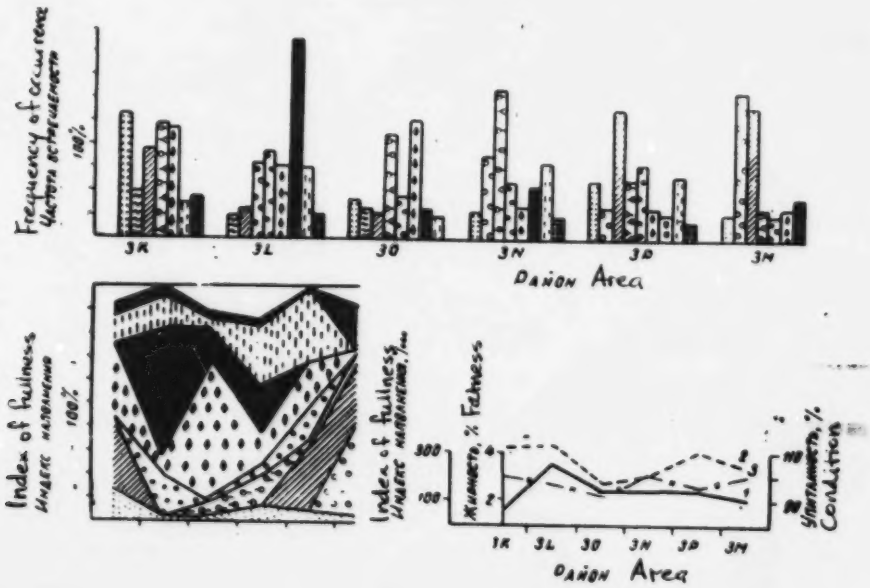

Fig. 6. Food composition and biological characteristics of cod juveniles: overall index of fullness (1), average fatness (2) and condition (3) in different areas. Nomenclature as in Fig. 5

On the N Newfoundland bank, the young of various species of worms (12.3%), decapods (29.9%) and capelin (11.7%) are added to the items listed above.

On the Grand Bank, capelin (25.7%) and sand lance (19.9%) predominate in the diet of cod juveniles; tens of fairly scarce species of gammarids (11%), worms (7.4%), shrimp and crabs (14%) are also encountered in their stomachs. At a depth of 100-150 m, euphausiids (35.7%) are the main food of cod juveniles (Fig. 7).

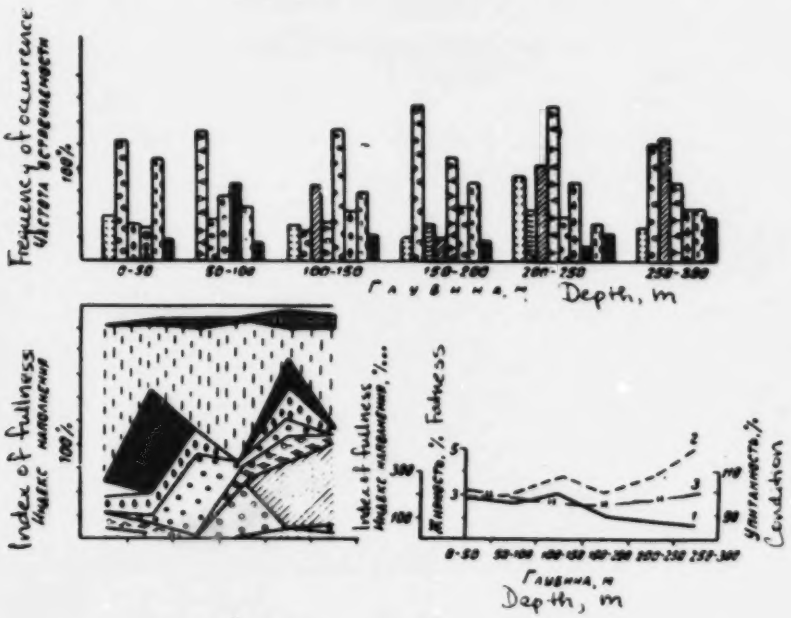

Fig. 7. Food composition and biological characteristics of cod juveniles at different depths. Nomenclature as in Fig. 5

In the SW Newfoundland microregion, the food of cod juveniles is extremely diverse taxonomically (see Table 3). Their stomachs were found to contain a large number of amphipod species, both benthic (frequency of occurrence 46.5%), and pelagic (11.1%), as well as shrimp and crabs (frequency of occurrence 52.1%); sand lance (13.2%) and capelin (10%) were also encountered, but only decapods played an important role by weight (60.4%) (see Fig. 6).

As the water temperature on the slopes of the Grand Bank increases and the bank waters heat through, some of the young migrate with the

capelin to their spawning grounds in the southeastern part of the shallows (Templeman, 1965; Kovalyov, Kurin, 1973) where, after the departure of the capelin, they feed on the eggs and fry of the latter. Amphipods predominate in the stomachs of the fish remaining on the southeastern slope of the bank; north of 44° N lat, the consumption of sand lance (54.4%) and euphausiids (17.7%) increases. The highest index of fullness (254.5‰) is noted in the St. John's microregion where, in addition to the above-mentioned organisms, the young of the cod feed on decapods (7.7%) and foraging capelin (14.1%).

The noted predominance of this or that food organism in the stomachs of cod juveniles is closely related to the distribution of these organisms and the depth at which the cod are found. *Themisto* fill the stomachs of the young cod from depths of 200-300 m (29.7-35.3%), euphausiids the stomachs of those from depths of 100-150 m (35.7%), and plankton the stomachs of juveniles caught at a depth of 150-200 m (23.7%). We found that young cod fed on sand lance in the shallow areas (45.8%), and on capelin everywhere (see Fig. 7).

The noted difference in the species composition of the food organisms encountered in the stomachs of cod juveniles depends on the time of the year and the spawning time of the capelin.

In April—May 1972, migrating capelin were concentrated along the southwestern slope of the bank (see Fig. 4); the frequency of occurrence of capelin in the stomachs of cod juveniles amounted to 45.8% in the SW Newfoundland microregion, and only 6% in the S Newfoundland microregion. The take of young cod in the southwestern part of the bank varied from 100 to 300 specimens per hour of trawling, whereas only a few (up to 20 per hour of trawling) were caught in the southeastern shallows.

In June—July 1971, during the spawning period of the capelin, the latter was encountered in 44.2% of the foraging fish in the South Newfoundland microregion, and in 27.8% of the fish in the SW Newfoundland microregion.

In May 1968 and 1969, cod juveniles fed on capelin predominantly on the slopes at depths up to 250 m both in the SW Newfoundland and South Newfoundland microregions (capelin was not observed in the shallow areas).

In April 1976 (during the survey period), the capelin had not yet begun its mass migration through the SW Newfoundland region; only 3% of the foraging cod had capelin in their stomachs, whereas the cod on the slope of S Newfoundland had begun to feed on capelin the month before. Up to the end of April and at the beginning of May, the young cod fed on capelin only on the slope, and to a smaller degree in the southern part (9%) than in the north (49%).

The catches of cod juveniles in the northern part of the microregion amounted to 175-2109 per hour of trawling.

In 1977, there was no capelin in the southeastern shallows up to the end of May. During the second ten days of June, after the rapid migration of the capelin from the St. John's microregion to the southeastern shallows for spawning, we observed an increase in the density of cod aggregations in the shallows. In May, 128-150 young cod were found in only three catches in the southeastern part of the shallows. The rest of the catches were much leaner. In June, about 30 centners of young cod was landed with a midwater trawl.

The sand lance is an important food of young cod on the Grand Bank; it is consumed by the cod mainly in the northern part of the southeastern slope at depths under 250 m, in the shallows at the southern end of the bank, and along its southwestern slope. More than ever before, the feeding of cod juveniles on sand lance was at its highest in May—June 1977, when the frequency of occurrence of this fish in cod stomachs reached 36 and 24% in the S and SW Newfoundland microregions respectively. The catches of young cod were high (734-1096 per hour of trawling) in the S Newfoundland microregion, and low (50-259 per hour of trawling) in the SW Newfoundland microregion.

The differences in the feeding of cod juveniles in individual areas of the southern slopes of the Grand Bank are more significant than on the North Newfoundland bank or Flemish Cap. For example, in June 1974, the cod in the northern part of the southeastern slope from 46 to 45° N lat. fed mainly on euphausiids, sand lance, and to a smaller degree amphipods. The catches of young cod varied from 160 to 921 per hour of trawling. Farther south along the slope from 44° N lat, the consumption of euphausiids and sand lance decreased, but the proportion of amphipods, *Themisto*, cumaceans and worms increased in the diet of the young cod. At the southern end of the bank, the frequency of occurrence

of euphausiids in the stomachs of cod juveniles again increased to 33%, though the latter foraged mainly on *Themisto* (83%). The catches of young cod diminished somewhat (maximum 200-234 per hour of trawling). During this period, the young cod in the shallow areas of the bank fed on amphipods, cumaceans, crabs, shrimp and worms in addition to capelin and sand lance. The food spectrum of the young was highly diverse, and the catches were small (up to 60 cod per hour of trawling).

A similar situation was observed in the southern part of the Barents Sea. The most intensive feeding of cod juveniles was observed in places where underyearlings of fish (cod, polar cod, herring) congregated; in places where underyearlings were scarce, the index of fullness of cod juveniles was comparatively low, and the catches decreased accordingly (Ponomarenko, 1958, 1961, 1968).

The difference in the species composition of the amphipods encountered in the stomachs of cod juveniles in different microregions is of unquestionable interest. On the N Newfoundland bank, St. Pierre and Flemish Cap, the amphipods are represented by three species of hyperiids (*Themisto abyssorum*, *Th. libellula* and *Th. compressa*), the most abundant being *Themisto compressa* f. *compressa* and *Th. compressa* f. *bispinosa*. In the southern microregions (SE and SW Newfoundland), cod juveniles foraged on gammarids (see Table 3), but the frequency of occurrence of most of them in the stomachs of young cod was insignificant.

Therefore, despite certain yearly and local differences, the basic food of young cod consists of capelin, sand lance, euphausiids and amphipods (Fig. 8). The highest index of fullness of cod juveniles was noted in 1973, and the lowest in 1974; the average annual fatness and condition factor were inversely dependent on the index of fuliness.

In addition to food composition, Fig. 6 contains data on the index of fullness, fatness and condition factor of cod juveniles in different regions of the Grand Bank. We can clearly see that the quantitative feeding indices tend to decrease from the north to south. The exception is St. Pierre bank where samples were taken in April during the spring foraging of the capelin. This is apparently due to the fact that the feeding conditions in the northern areas are somewhat better than in the southern areas. The most favourable feeding conditions are noted in the St. John's microregion where the fatness and index of fullness reached

the highest levels (4.3% and 250‰). The highest fatness was noted in cod juveniles at depths of 100-150 and 250-300 m (3.8 and 5% respectively) when they fed on capelin, euphausiids and *Themisto*. These food components apparently provide more calories. As for the condition factor, it showed no clearly defined differences from one area to the next during the period of investigation. According to N.S. Novikova (1963), an inverse relationship between the index and fullness and fatness is usually observed in the young of cod. The direct relationship derived by us, as well as the absence of any relationship between these two factors and the condition factor indicate that the cod juveniles on the Newfoundland banks do not manage to attain maximum fatness and condition during the spring—summer period.

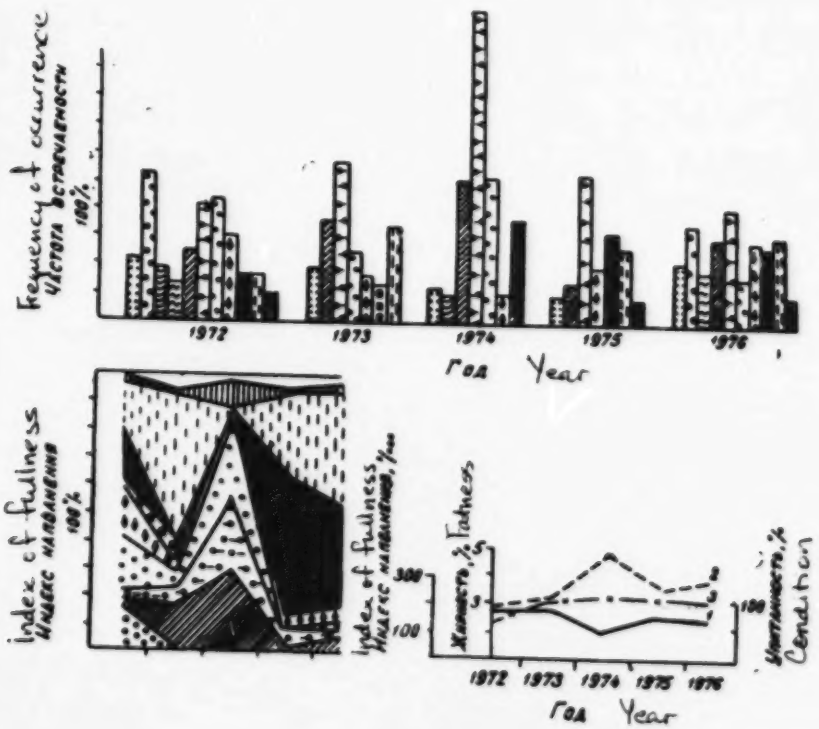

Fig. 8. Food composition and biological characteristics of cod juveniles during different years. Nomenclature as in Fig. 5

From the seasonal point of view, the young of cod on the Grand Banks of Newfoundland have the following feeding pattern (Fig. 9). Feeding on capelin is fairly intense throughout all the months studied, with a certain increase in spring—beginning of summer (88.5%), and a decrease in September (1.6%). The young of cod fed on sand lance in the shallow areas in April (28.1%), July (24.7%) and September (69.8%). *Themisto* and euphausiids were consumed mainly during the summer months, *Themisto* in June (24.8%) and August (66%), and euphausiids in May (18%) and July (20.5%). Decapods (crab, shrimp) were an important part of the cod's diet, but they, like worms, mollusks and benthic amphipods, were a staple everywhere, and did not manifest a clearly defined seasonal periodicity. Plankton was one of the leading food components on Flemish Cap in April (28%). A diet of capelin and sand lance greatly affects the fatness and index of fullness of young cod. Substantial indexes of fullness were noted in April (155‰) and July (165.5‰). High indices of fatness were noted in May (4.3%), and especially in August (6.11%) after foraging on capelin and sand lance. Each month, the fatness and index of fullness of the cod showed an inverse relationship (see Fig. 9).

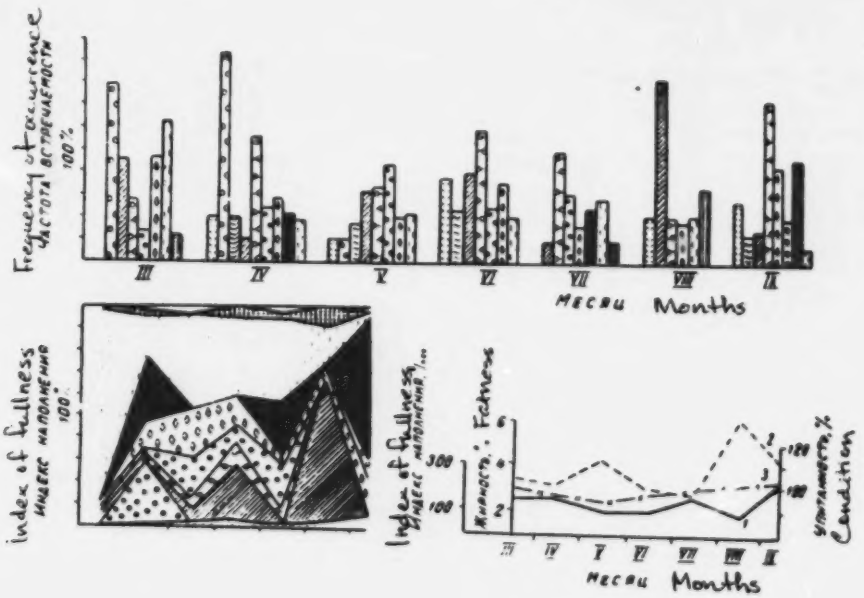

Fig. 9. Seasonal feeding pattern of cod juveniles. Nomenclature as in Fig. 5

A comparison of the relative condition of cod juveniles from month to month shows that it increases from spring to autumn. The lowest condition factor (93.5%) was observed in May, and the highest (104%) in September.

Conclusions. On the Newfoundland Shelf, cod juveniles keep mainly to depths of less than 350 m where the temperature of the water at the bottom varies from -1 to 3°C.

The highest concentrations of cod up to 40 cm in length were observed in the frontal waters on the outer edge of the shelf; juveniles were particularly abundant on the steep slopes in the uppermost parts of the canyons.

The fish kept mainly below the layer of water with minus temperatures; the young congregated in below-zero waters usually when feeding on foraging capelin.

The partial migration of cod juveniles from the southwestern part of the shallows and slopes of the southern end of the Grand Bank to its southeastern shallows was due to the increase in water temperature on the slopes and the spawning migration of the capelin.

The diet of cod juveniles in the vicinity of the Grand Bank consists mainly of capelin (15.7% by mass), sand lance (26%), euphausiids (91.6%), hyperiids (14.6%), and gammarids (18.1%).

The predominance of this or that food in the diet of young cod depends on the distribution of the food and the depth inhabited by the cod. The concentrations of capelin and sand lance make the northern and northeastern areas the most favourable foraging grounds. The least favourable feeding conditions are found in the northern and northeastern areas.

The fatness, condition factor and index of fullness of cod juveniles on the Grand Banks are the highest in the St. John's microregion, and the lowest in the SW Newfoundland microregion.

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